VIIRS SNOW COVER PRODUCTS: CURRENT STATUS AND PLANS

Peter Romanov
CREST/CUNY at NOAA/STAR
peter.romanov@noaa.gov

Outline

- VIIRS Binary Snow Cover and Fractional Snow Cover
  - Definition, requirements
  - NDE product performance
  - NOAA-20 Snow Product Status
  - Further algorithm enhancements

Cal/Val Team Members

Name	Organization	Roles and Responsibilities
Jeff Key	NOAA/NESDIS	Cryosphere Team Lead
Peter Romanov	CUNY/CREST	Snow Products Lead
John Woods	NOAA/NIC	User/Applications
William Lapenta, Jiarui Dong	NOAA/NWS	User/Applications

JPSS ESPC (JERD) Requirements

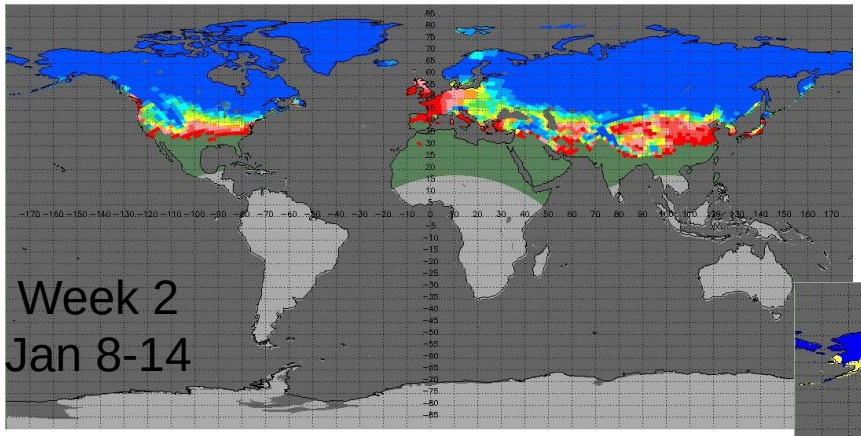
- Binary snow map:
  - Snow/no snow discrimination
  - 90% probability of correct typing
    - Over climatologically snow-affected areas

- Snow fraction:
  - “Viewable” snow fraction
  - 20% accuracy

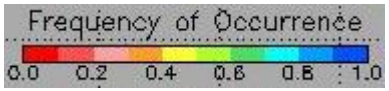
- Both products are
  - Clear-sky daytime-only land products
  - Derived at 375 m resolution

- Both products depend on the accuracy of VIIRS cloud mask.

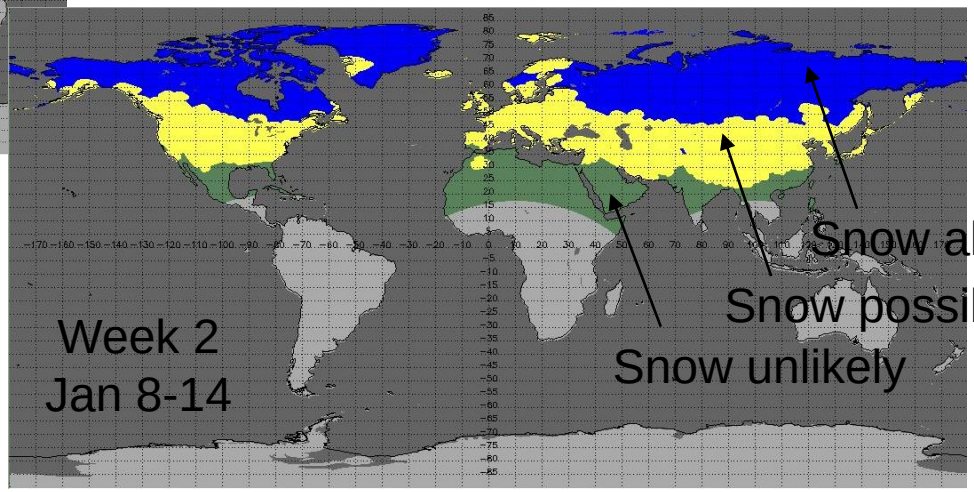
Climatologically snow-affected areas



Weekly climatic snow cover occurrence



Snow cover occurrence categories



- Accuracy estimates are provided for the “snow possible” region (shown in yellow)
- Boundaries of the “snow possible” region change with time during the year

Binary Snow Cover

NDE Binary Snow Algorithm

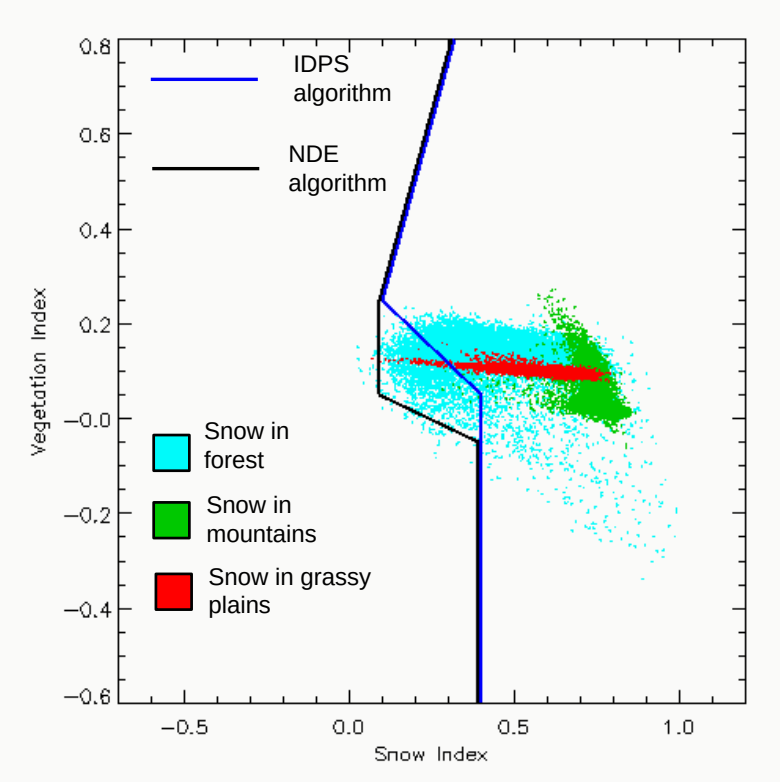
Two-stage algorithm:

1. Spectral threshold tests

- VIIRS Bands I1, I2, I3, I5
- NDVI, NDSI
- Improved snow identification in forest

2. Consistency tests

- Eliminate spurious snow



Consistency tests (applied to "snow" pixels) :

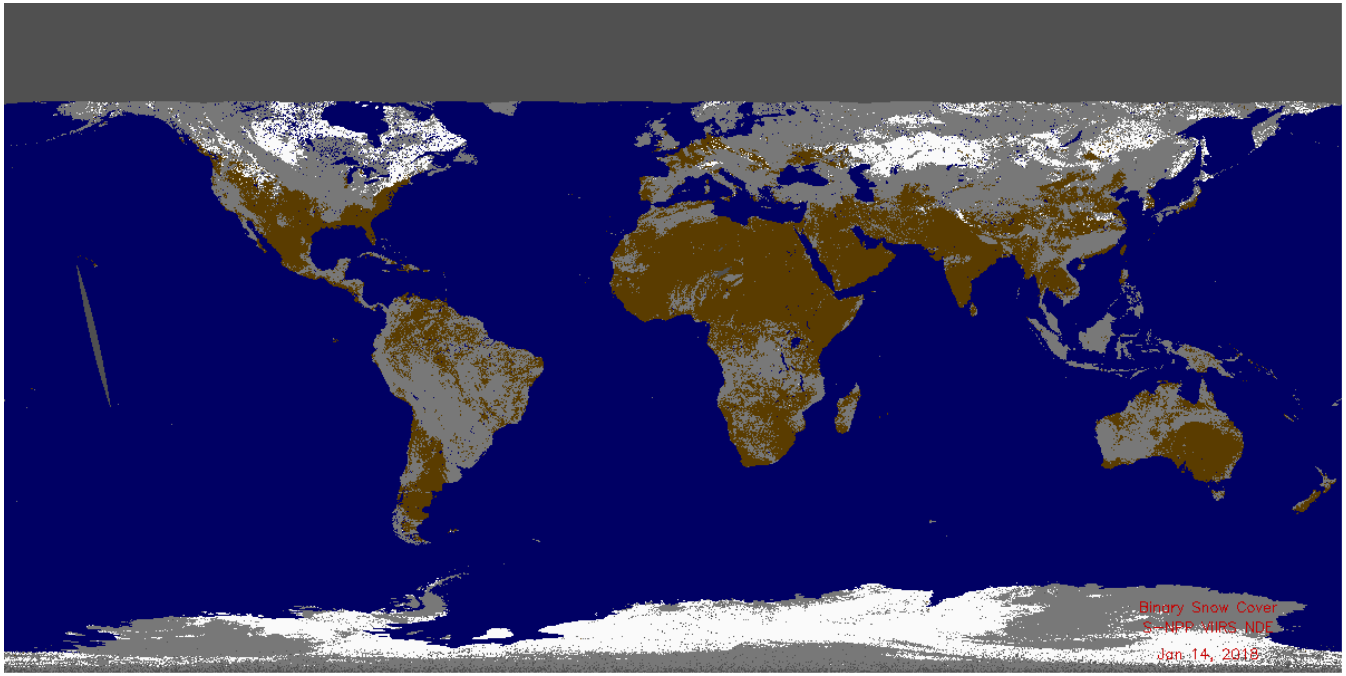
- Snow climatology
- Surface temperature climatology
- Spatial consistency
- Temperature spatial uniformity

Algorithm applied only:

- Over land surface (as per land/water mask)
- Over clear sky scenes (as per external cloud mask, confidently clear only)
- During daytime

NDE Daily Product Monitoring

- Granules are aggregated and gridded to 0.01^0 geographical projection
- Product quality and performance is evaluated by:
  - Visual examination (includes comparison with true color imagery)
  - Comparison with IMS and in situ data

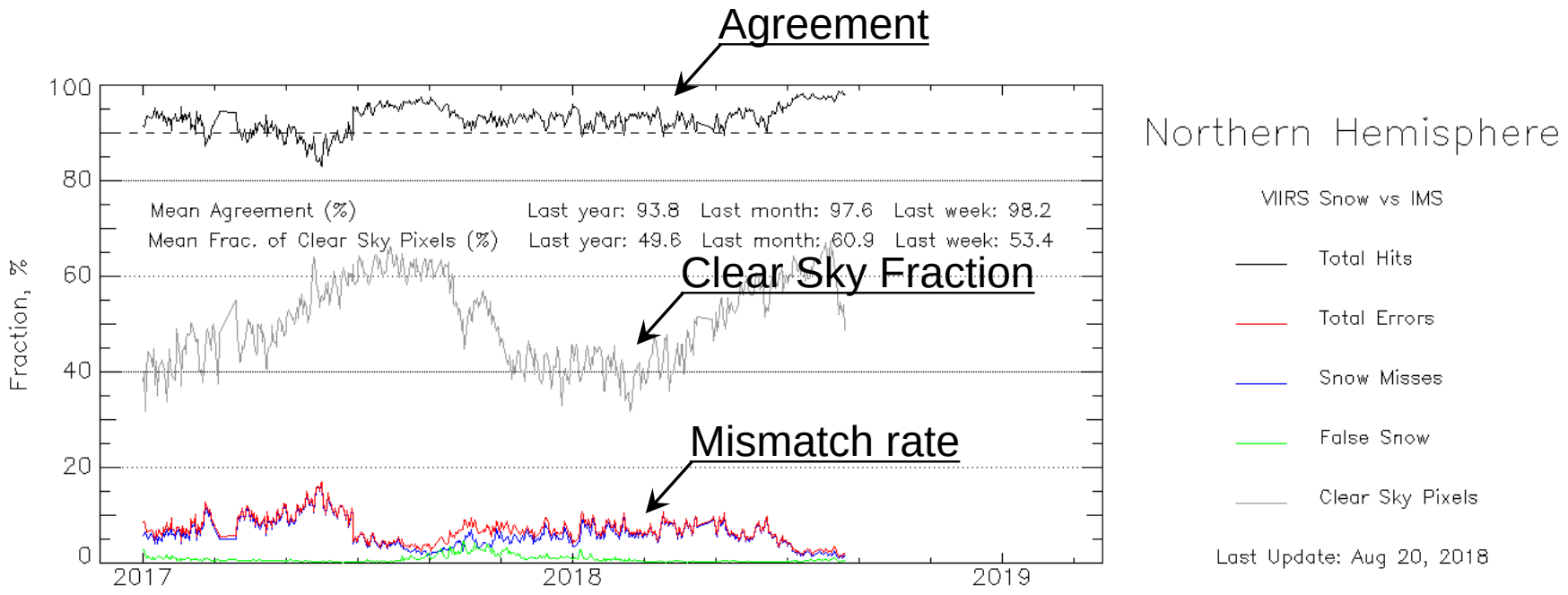


- On the Web (map updated daily)
  http://www.star.nesdis.noaa.gov/smcd/emb/snow/viirs/viirs-snow-fraction.html
  http://www.star.nesdis.noaa.gov/jpss/EDRs/products_snow.php

SNPP VIIRS NDE Snow vs IMS

SNPP VIIRS Binary Snow Map : Daily agreement to IMS

Climatologically snow-affected areas only

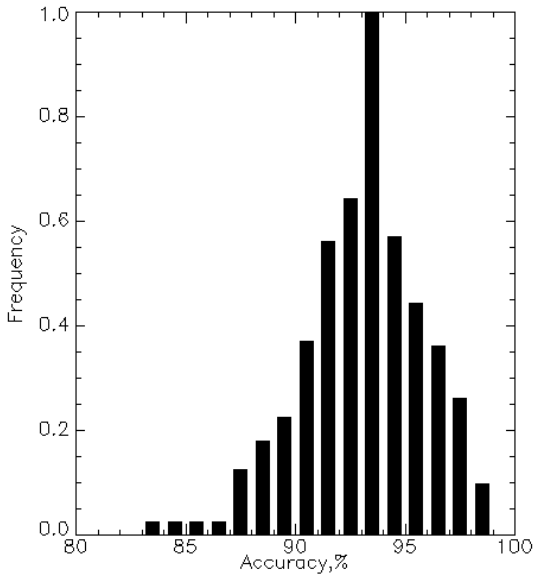


- Agreement rate mostly exceeds 90%
- IMS maps more snow than VIIRS
- VIIRS clear sky fraction over land: ~ 40- 60%, varies with season

SNPP NDE Binary Snow: Accuracy

Daily rate of agreement of VIIRS NDE snow maps*

- To IMS (NH, over “snow possible” area)
  - Mean: 93.8%,
  - Range: 85-97%
- To in situ reports (CONUS & Southern Canada)
  - Mean: 93.3%
  - Range: 82-98%



Statistics of VIIRS NDE vs IMS daily agreement rate over NH

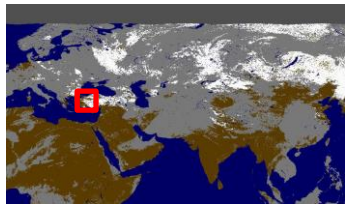
* Assessment based on 2017-2018 winter season data of SNPP VIIRS

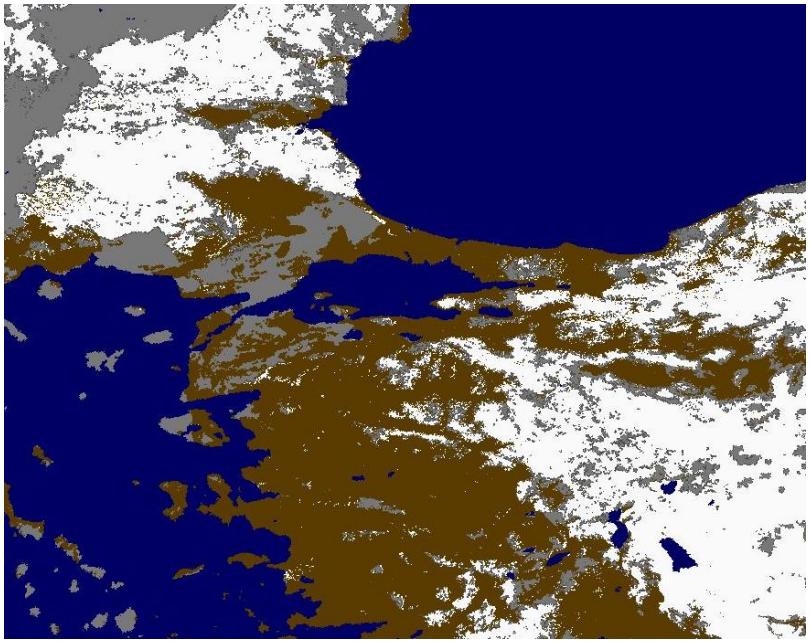
Product	Requirement	Performance
Binary Snow	90% Correct Typing	Mean: 93-94% Range: 82-98%

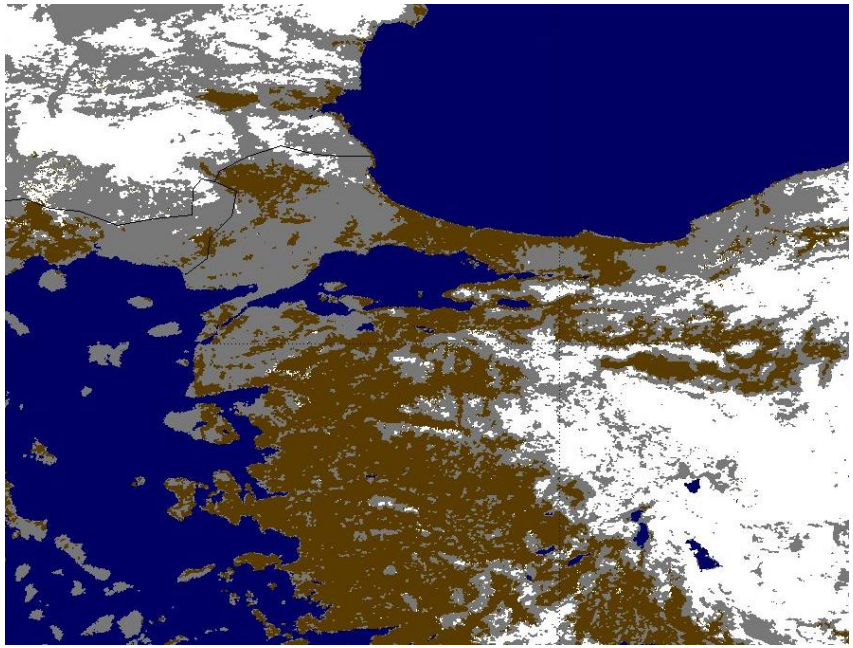
Product generally satisfies current requirements

NDE vs IDPS Binary Snow Product

NDE: Better delineation of the snow cover boundary due to less conservative cloud masking in the snow/no-snow transition zone







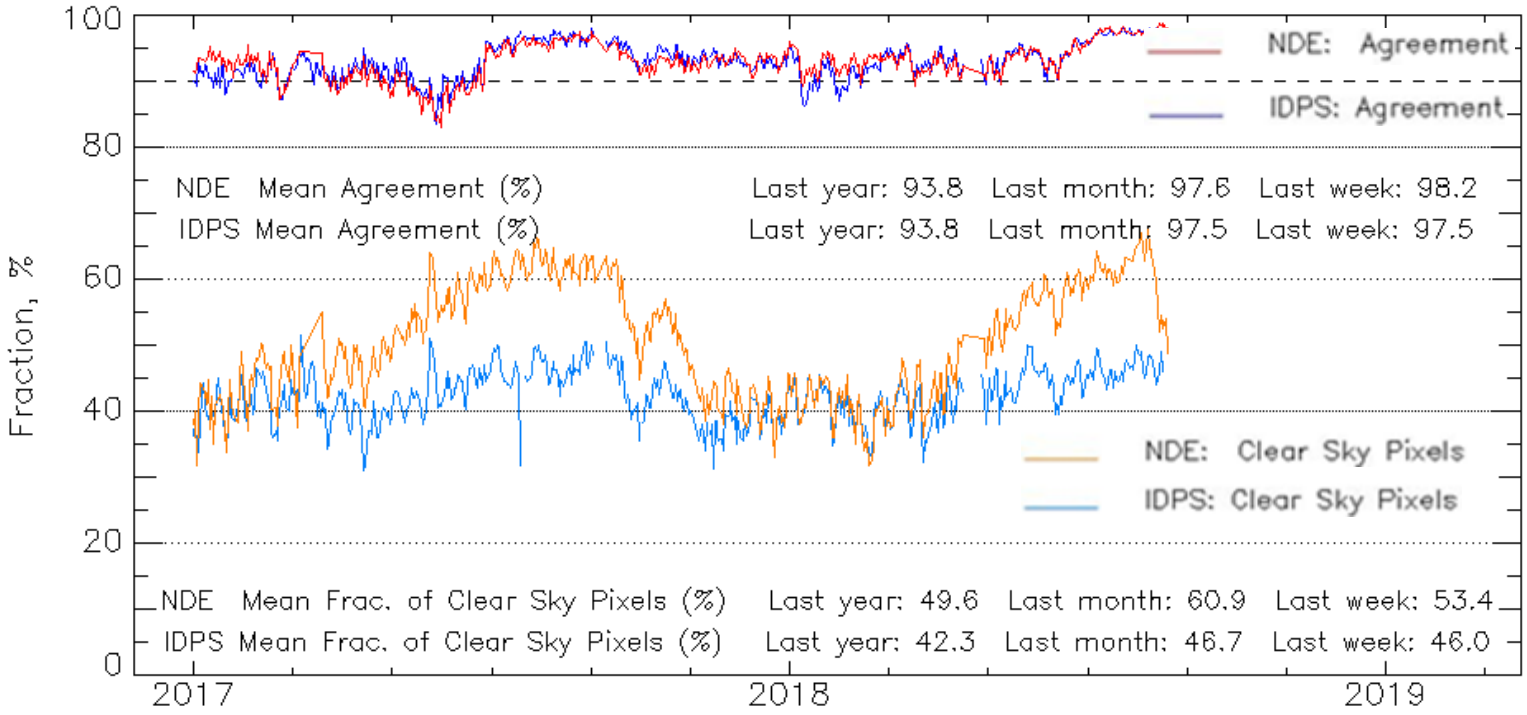
NDE, Feb 2 2017

IDPS, Feb 2 2017

snow land cloud No data

NDE & IDPS: Binary Snow Accuracy

IDPS and NDE products vs IMS over N.Hemisphere



NDE vs IDPS

- Similar accuracy as compared to IMS
- NDE: More clear sky views (less clouds), hence, better area coverage

Snow Fraction

Enterprise (NDE) Snow Fraction

Viewable Snow Fraction: Two algorithms

1. Visible reflectance-based

$$\textbf{SnowFraction} = (R - R_{land}) / (R_{snow} - R_{land})$$

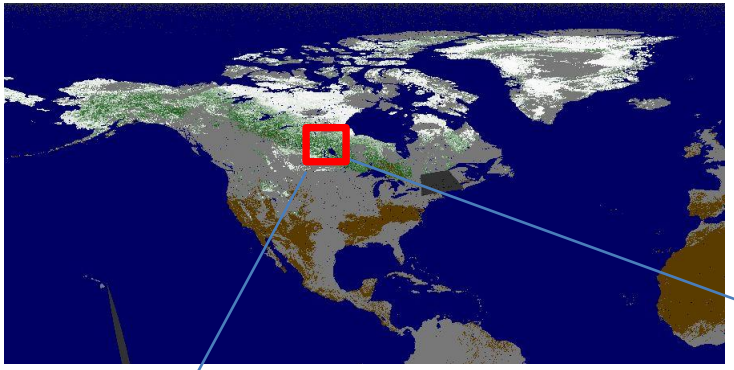
- Uses VIIRS band I1 (0.6 µm) reflectance (**R**)
- End-members (R_{land}, R_{snow}) account for surface reflectance anisotropy
- Algorithm used with GOES Imager and AVHRR; Approach similar to GOES-R

2. NDSI-based

$$\textbf{SnowFraction} = -0.01 + 1.45 * \textbf{NDSI}$$

- $\textbf{NDSI} = (R_{0.6} - R_{1.6}) / (R_{0.6} + R_{1.6})$
- MODIS heritage algorithm
- Algorithm needs to be locally tuned,
- NDSI strongly depends on the viewing-illumination geometry
- NASA stopped generating NDSI-based snow fraction since Collection 6

Snow Fraction: Two Algorithms

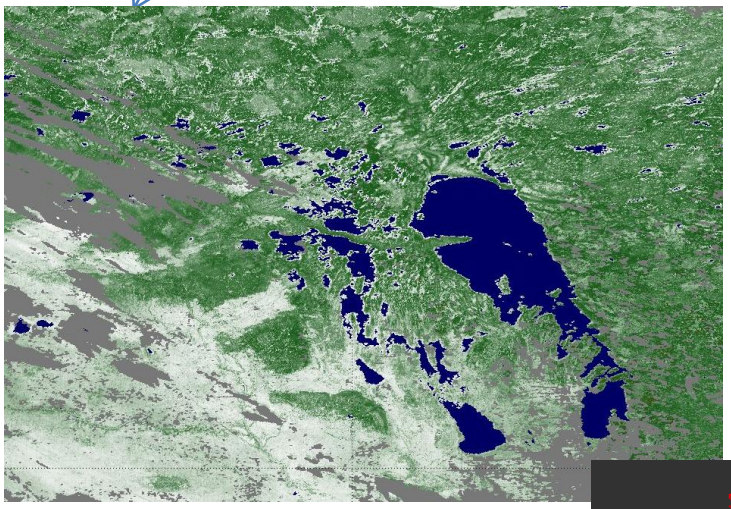


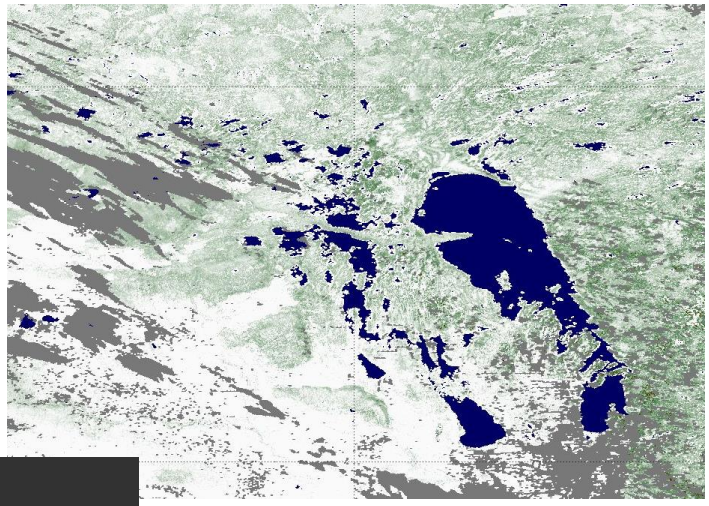
Reflectance-based Snow Fraction vs NDSI-based snow fraction

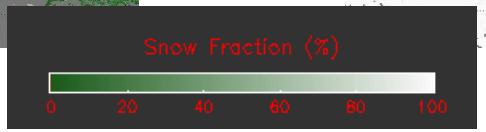
- Generally similar snow fraction patterns
- NDSI snow fraction is unrealistically large in the forest

Reflectance-based snow fraction

NDSI-based snow fraction







Clouds are shown in gray

Snow Fraction Evaluation

Direct accuracy assessment is impossible: no in-situ measurements

Reflectance-based snow fraction:

Theoretically estimated accuracy: 10-20%

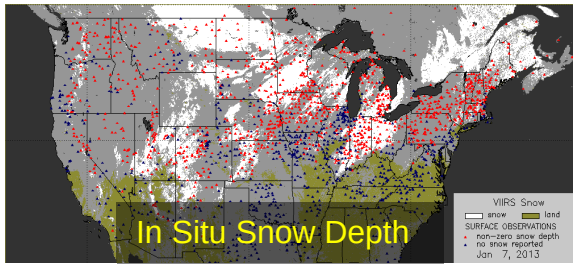
SNPP VIIRS derived snow fraction demonstrates
- Consistency with the forest cover distribution (negative correlation)
- Consistency with in situ snow depth (positive correlation)
- Robust reproducibility of spatial patterns of snow fraction

Comparison with Landsat: mean agreement ~ 17%, range: 5-25%
- Estimates are not independent, limited validity

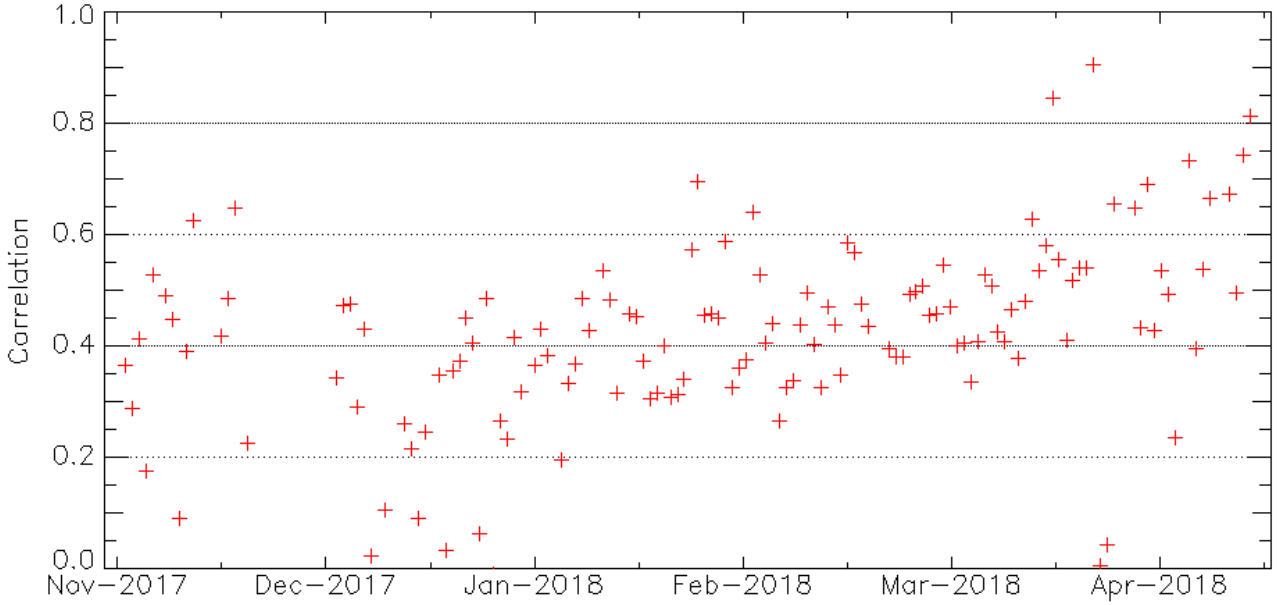
Product is expected to meet the requirements

Consistency with Snow Depth

- VIIRS Snow Fraction vs matched In situ Snow Depth
- Correlation calculated over Great Plains
- 10 to 300 match-ups daily
- 5-30 cm mean snow depth
- Correlation is positive meaning that estimated snow fraction is consistent with the snow depth data

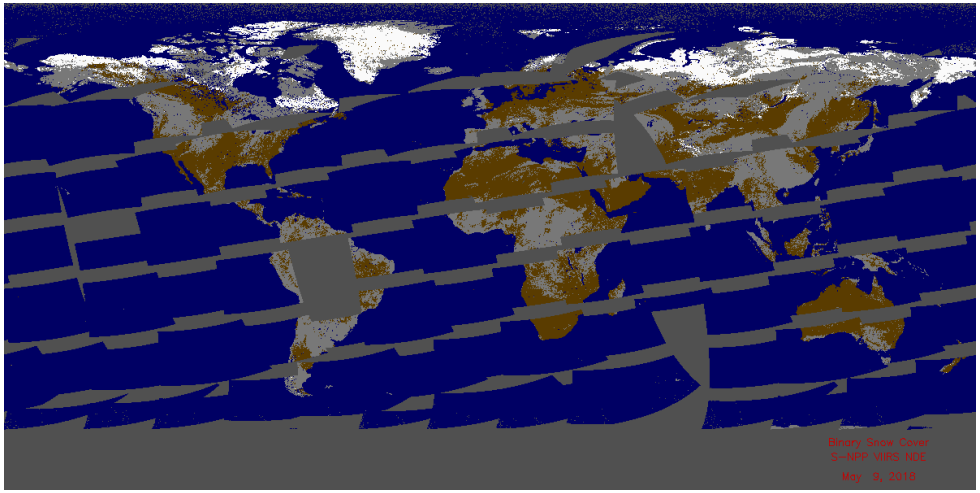


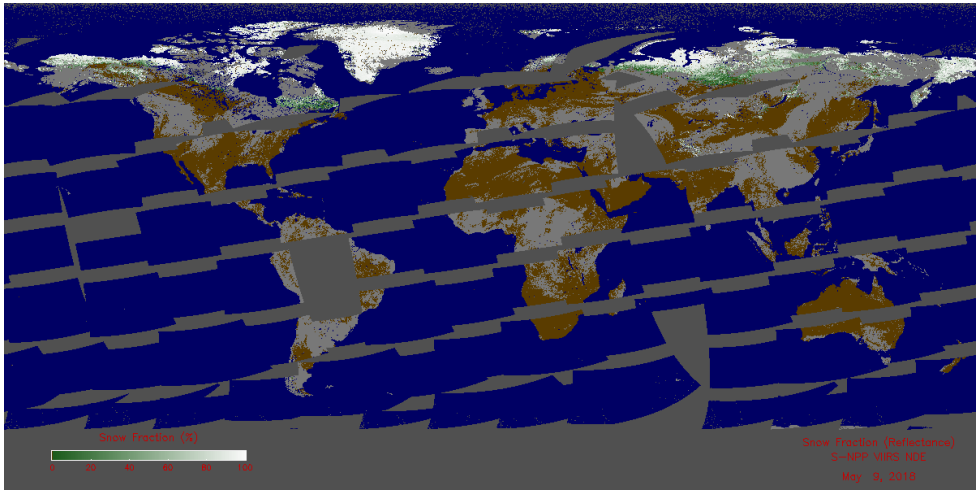
Snow Fraction vs Snow Depth Daily Correlation



Status of NOAA-20 NDE Snow Product

NOAA-20 NDE Gridded Snow





Produced since May 2018

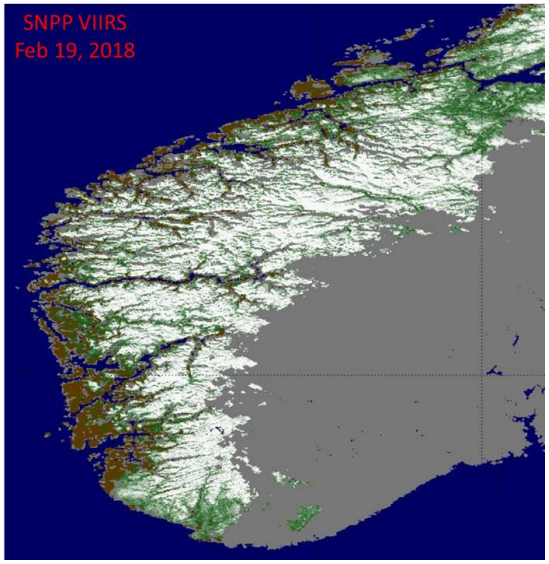
Algorithms implemented correctly

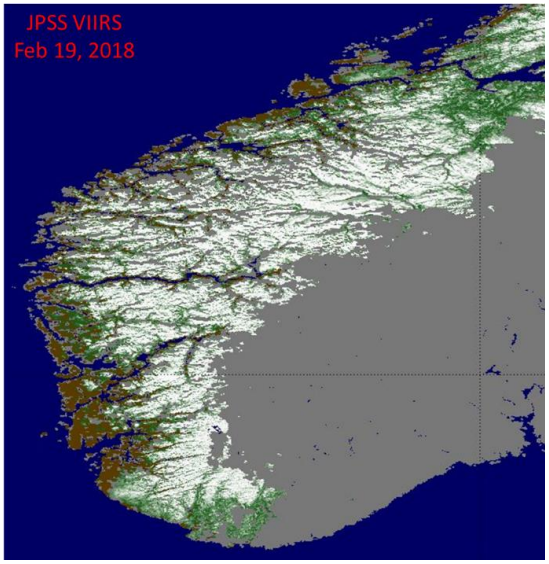
Missing granules, hence incomplete daily area coverage

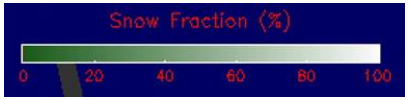
Beta maturity in June 2018

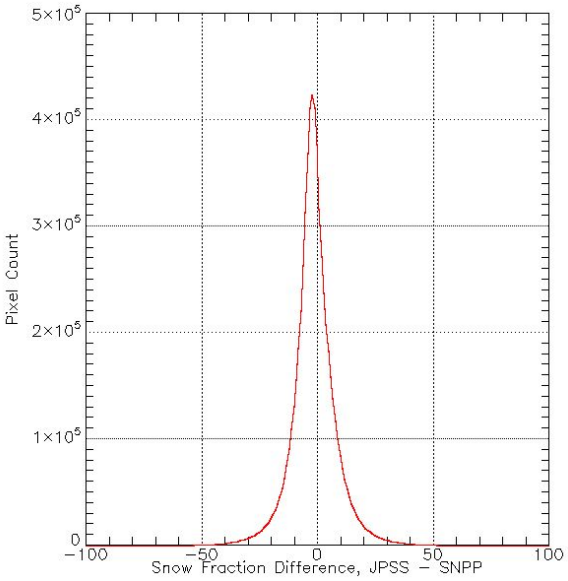
Products are expected to satisfy requirements once the missing granule problem is fixed

NOAA-20 vs SNPP Snow









Matched N20 and SNPP snow fraction difference statisics

NOAA-20 and SNPP Snow Products

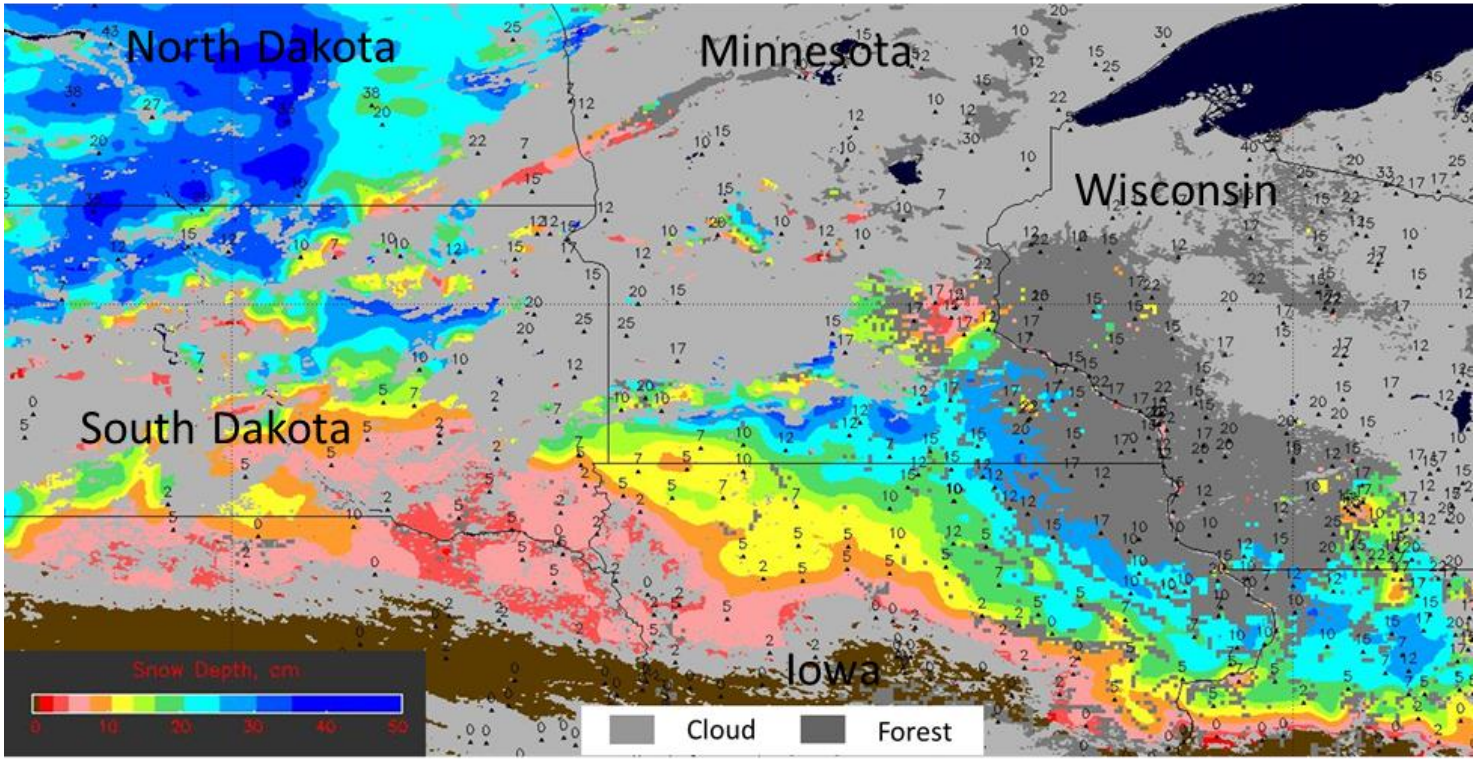
- ~ 99% agreement on the snow cover (yes/no)
- ~ 6% mean difference in estimated snow fraction
- Estimates are based on IDPS,
  NDE N20 and SNPP differences should be similar

Further Enhancements

Further Enhancements

Snow depth estimates

- Employs correlation between snow fraction and snow depth
- Retrievals limited to plain non-forested areas
- “Saturation” occurs at 30-40 cm snow depth



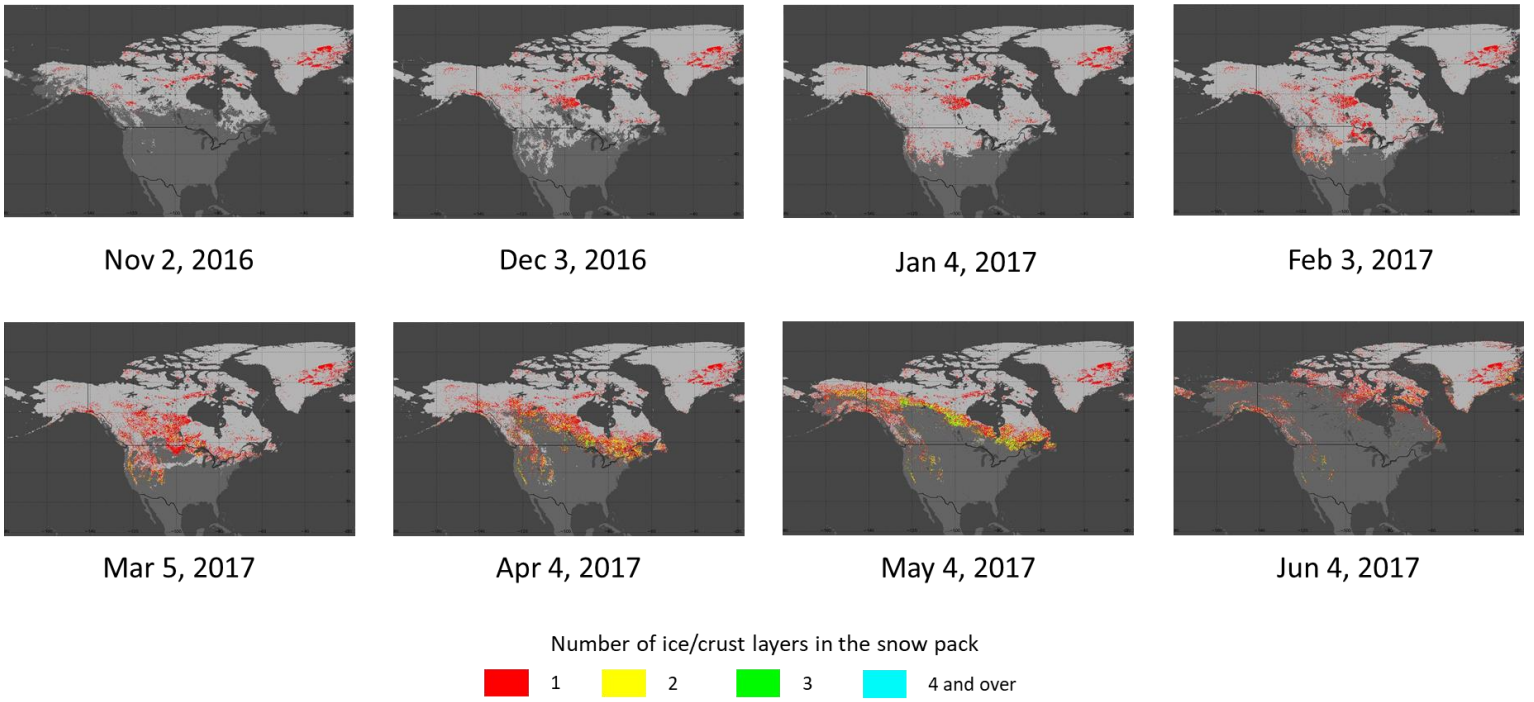
Snow Depth
Dec 18, 2016

Numbers present the snow depth observed in situ

Further Enhancements, Cont'd

Ice/crust layers in the snow pack

- Needed in microwave retrievals, snowmelt runoff modelling
- Uses surface temperature to identify snow melt/freeze
- Calculates the number of melt-freeze events

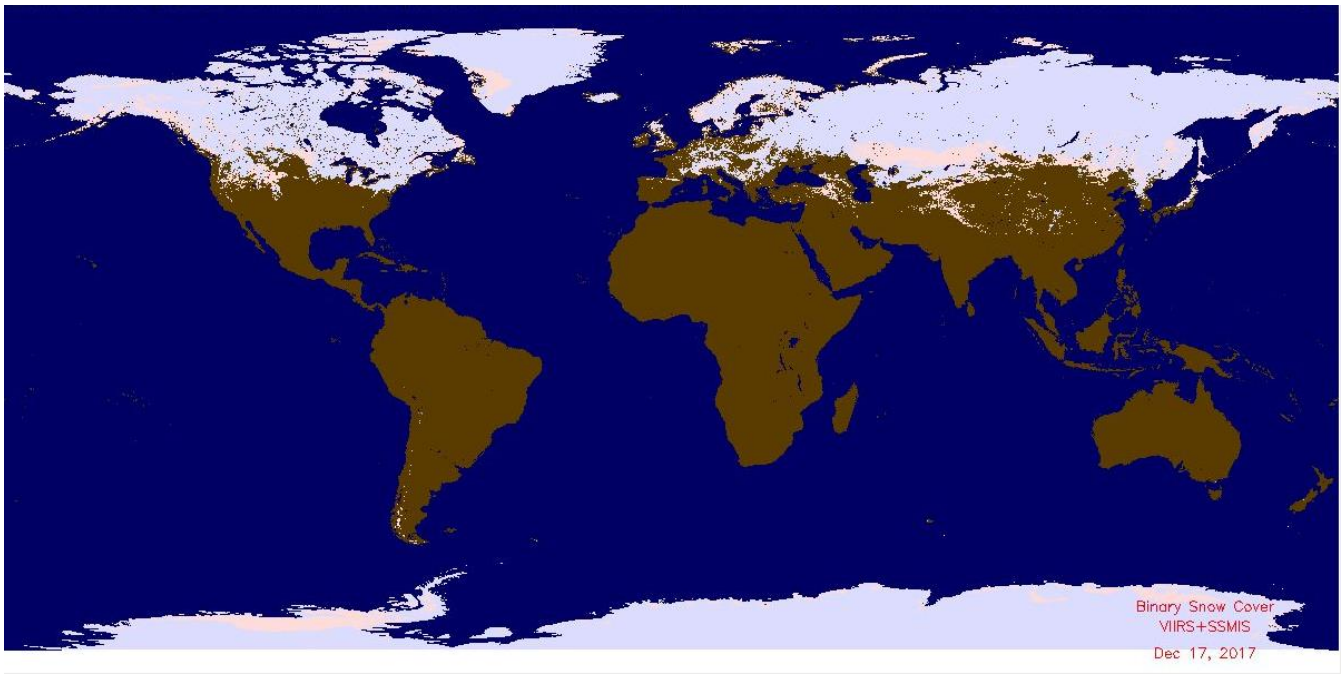


Ice/crust layers in the snow pack during the 2016-2017 winter season

Further Enhancements, Cont'd

Gap-free blended snow cover map (VIIRS + microwave)

- Involves GCOM AMSR2 or DMSP/SSMIS snow retrievals
- Uses GMASI approach to merging vis/IR and MW data
- Effective spatial resolution: 1 km clear sky, 8 km cloudy
- May add ice cover to the gridded product



Summary

SNPP snow algorithms and products

- Operational within NDE
- Demonstrate robust performance
- Satisfy requirements

NOAA-20 snow products

- Snow algorithms appear to perform correctly
- Granules are missing, incomplete coverage
- Beta maturity in June 2018, Provisional: later this year

Further improvements of algorithms are planned

New products are being developed